



# Technical Report Series on the Biosystem-Aerosphere Study (BOREAS)

*William L. Munn and Sara K. Conrad, Editors*

**244**

## BOREAS TGB-12 Soil Carbon Data

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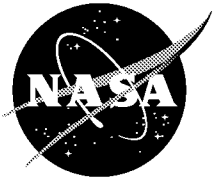
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## **Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)**

*Forrest G. Hall and Sara K. Conrad, Editors*

### **Volume 244**

## **BOREAS TGB-12 Soil Carbon Data over the NSA**

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# **BOREAS TGB-12 Soil Carbon Data over the NSA**

Susan Trumbore, Jennifer Harden, Eric Sundquist, Greg Winston

## **Summary**

The BOREAS TGB-12 team made measurements of soil carbon inventories, carbon concentration in soil gases, and rates of soil respiration at several sites to estimate the rates of carbon accumulation and turnover in each of the major vegetation types. TGB-12 data sets include soil properties at tower and selected auxiliary sites in the BOREAS NSA and data on the seasonal variations in the radiocarbon content of CO<sub>2</sub> in the soil atmosphere at NSA tower sites. The sampling strategies for soils were designed to take advantage of local fire chronosequences, so that the accumulation of C in areas of moss regrowth could be determined. These data are used to calculate the inventory of C and N in moss and mineral soil layers at NSA sites and to determine the rates of input and turnover (using both accumulation since the last stand-killing fire and radiocarbon data). This data set includes physical parameters needed to determine carbon and nitrogen inventory in soils. The data were collected discontinuously from August 1993 to July 1996. The data are stored in tabular ASCII files.

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## **1. Data Set Overview**

### **1.1 Data Set Identification**

BOREAS TGB-12 Soil Carbon Data over the NSA

### **1.2 Data Set Introduction**

The data presented here include physical parameters needed to determine carbon and nitrogen inventory in soils (bulk density, %C (both as organic C and CaCO<sub>3</sub>), %N, C/N ratio in organic matter) as well as <sup>14</sup>C measurements of organic matter. Soil moisture data (good only for the day of collection) and brief descriptions of soil horizons are also included.

### **1.3 Objective/Purpose**

The objectives of the research were:

- To estimate rates of carbon input, turnover, and accumulation in the soils of each of the major vegetation types at the BOREal Ecosystem-Atmosphere Study (BOREAS) study sites. The primary tool will be measures of  $^{14}\text{C}$  content in soils, litter, and soil atmospheres, and measurements of  $\text{CO}_2$  emissions from the soil.
- To relate our estimates of dynamics of soil carbon to ecosystem models of the carbon cycle, to other measures of C cycling dynamics, to regional models of soil carbon accumulation, and to spatial and temporal models of soil moisture and drainage.

### **1.4 Summary of Parameters**

The key parameters include brief description of the sample/horizon (e.g., brown decomposed moss, clay), soil pH, soil moisture, bulk density, organic carbon and nitrogen content, inorganic carbon content, and radiocarbon ( $^{14}\text{C}$ ) content.

### **1.5 Discussion**

Carbon inventories and  $^{14}\text{C}$  give information that is needed to determine C storage, as well as to determine the accumulation rate of C (in nonsteady-state systems) or the turnover rate of C (in systems where C turnover rate is less than soil or disturbance age). These data are checked using the isotopic composition of respired  $\text{CO}_2$  (which will reflect the  $^{14}\text{C}$  content of root respiration and decomposing organic matter), and by a knowledge of soil C inputs and losses. See Section 3 (below) for details.

### **1.6 Related Data Sets**

BOREAS TE-20 NSA Soil Lab Data

BOREAS TE-20 Soils Data over the NSA-MSA and Tower Sites in Raster Format

BOREAS TGB-01 Soil  $\text{CH}_4$  and  $\text{CO}_2$  Profile Data over the NSA

BOREAS TGB-03 Soil  $\text{CO}_2$  and  $\text{CH}_4$  Profile Data over the NSA

BOREAS TGB-12  $^{222}\text{Rn}$  Activity Data over the NSA

BOREAS TGB-12  $^{222}\text{Rn}$  Flux Data over the NSA

BOREAS TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format

BOREAS TGB-12 Isotopic Carbon Dioxide Data over the NSA

## **2. Investigator(s)**

### **2.1 Investigator(s) Name and Title**

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U.S. Geological Survey

Menlo Park, CA

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### **2.2 Title of Investigation**

Input, Accumulation and Turnover of Carbon in Boreal Forest Soils

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## **3. Theory of Measurements**

Soil moisture and soil C and N inventory are relatively common and straightforward measurements to make and will not be discussed in detail here.

$^{14}\text{C}$  is produced in the stratosphere by the  $^{14}\text{N}$  (n,p)  $^{14}\text{C}$  reaction. The  $^{14}\text{C}$  atom is oxidized rapidly to  $^{14}\text{CO}$ , which has a lifetime of months before it is oxidized to  $^{14}\text{CO}_2$ . Most  $^{14}\text{C}$  production occurs in the stratosphere, but the long lifetime of  $\text{CO}_2$  enables  $^{14}\text{CO}_2$  to become well mixed throughout the troposphere. The steady-state  $^{14}\text{C}$  content of the atmosphere is determined by the exchange of carbon in  $\text{CO}_2$  with that in ocean and biospheric reservoirs. Because of the relatively rapid

cycling of carbon between the atmosphere and living biomass, most plants maintain a  $^{14}\text{C}$  specific activity (or  $^{14}\text{C}/^{12}\text{C}$  ratio corrected for mass-dependent isotope fractionation effects) that equals that of atmospheric  $\text{CO}_2$ . Similarly, animals reflect the  $^{14}\text{C}/^{12}\text{C}$  of the plants (or animals) they consume. Upon the death of an organism, the  $^{14}\text{C}$  in its tissues is no longer replenished, and decays with a half life of 5730 years. If the tissue remains intact and isolated from exchange, the  $^{14}\text{C}/^{12}\text{C}$  ratio may be used to indicate the time since the death of the organism. This is the basis for radiocarbon dating.

Calculation of a radiocarbon age requires the assumption that the  $^{14}\text{C}$  content of the carbon originally fixed in plant tissues equaled that of the atmospheric  $\text{CO}_2$  in 1950 (0.95 times the activity of oxalic acid, or Modern). In fact, the  $^{14}\text{C}$  content of the atmosphere has varied with time because of changes in the production rate of  $^{14}\text{C}$  (cosmic ray flux and magnetic field variations) and because of changes in the distribution of carbon among ocean, biosphere, and atmospheric reservoirs. These variations, deduced from the  $^{14}\text{C}$  content of cellulose of known age taken from the annual growth rings of trees, are generally less than 10% over the past 7,000 years. More recent changes in the  $^{14}\text{C}$  content of atmospheric  $\text{CO}_2$  have resulted from dilution by  $^{14}\text{C}$ -free fossil-fuel-derived carbon and by the production of  $^{14}\text{C}$  during atmospheric testing of thermonuclear weapons (bomb  $^{14}\text{C}$ ). The latter effect dominates other natural and fossil fuel effects, as the atmospheric burden of  $^{14}\text{C}$  was approximately doubled in the few years preceding the implementation of the Nuclear Test Ban Treaty in 1964. This isotopic spike in the global carbon system provides a means for radiocarbon to be a useful tracer of carbon cycle processes on time scales of decades.

We express  $^{14}\text{C}$  data in the geochemical  $\delta$  notation, the deviation in parts per thousand (per mil) from an absolute standard (95 times the activity of NBS oxalic acid measured in 1950). In this notation, zero equals the  $^{14}\text{C}$  content of 1895 wood, positive values indicate the presence of 'bomb' radiocarbon, and negative values indicate the predominance of C fixed from the atmosphere more than several hundred years ago.

One important correction made in calculating the  $\delta^{14}\text{C}$  value is the  $^{13}\text{C}$  concentration is needed to account for isotopic fractionation effects. For example, consider that the  $\delta^{14}\text{C}$  difference between atmospheric  $\text{CO}_2$  and carbon fixed during photosynthesis by  $\text{C}_3$  plants is approximately 20. Since the mass difference between 12 and 14 is twice that between 12 and 13, the fractionation of  $^{14}\text{C}$  will be roughly twice that of  $^{13}\text{C}$ . The  $^{14}\text{C}$  contents of a tree and the  $\text{CO}_2$  that it is fixing through photosynthesis will differ by approximately 40%. To account for fractionation effects, the sample (with  $\delta^{13}\text{C}$  of  $\delta$ ) and standard are corrected to a constant  $^{13}\text{C}$  content. The standard oxalic acid is corrected in the same way, to -19 per mil (see references in Section 17 for more detail).

For seeds and deciduous leaves that represent a single year's growth, the  $^{14}\text{C}$  content of recent samples may be used to determine the age of a sample to within a year or two. The  $^{14}\text{C}$  content of the sample is compared to the  $^{14}\text{C}$  record of atmospheric C in the Northern Hemisphere (see Burcholadze reference in Section 17 for an example). Evergreen needles, that may average several years' growth, will be less easily interpreted.

For samples prior to 1960, radiocarbon ages in years may be calculated from the given Delta values as  $-8033 \cdot (\ln(\text{Delta} \cdot 995/1000 + 1))$ . The conventional radiocarbon age must be converted to a calibrated age using the tree-ring-based calibration curves that correct for known variations in atmospheric  $^{14}\text{C}$  over time. Both ages are usually rounded to the nearest decade or pentad.

One application of radiocarbon to soil science is the  $^{14}\text{C}$  dating of charcoal and plant macrofossils to determine the accumulation rate of C in vertically aggrading soils (peat or moss).

Unlike the closed systems represented by intact macrofossils, such as seeds or pollen, bulk Soil Organic Matter (SOM) is a heterogeneous reservoir with a variety of turnover times, to which carbon is continuously added (as new plant matter) and lost (as leached organic carbon or  $\text{CO}_2$ ). The radiocarbon content of SOM can not be interpreted as a 'date,' but represents the average age of a carbon atom in this reservoir.

The breakdown of C into faster and slower cycling pools may be determined by combining several approaches (see the articles in the reference list for more information).

For soils that are accumulating organic matter, the Harden et al. (1992) approach is used. The

upward accumulation of carbon in feathermoss is modeled as a time sequence described by inputs and decomposition according to the following equation:

$$dC/dt = I - kC \quad (1)$$

$$C_t = I/k(1 - \exp(-k \cdot t)) \quad (2)$$

where C is carbon mass in units of mass per area, t is time, I is input rate in mass per area per year, and k is a decomposition coefficient in units of time<sup>-1</sup>. This approach assumes that decomposition is proportional to total mass.

Two approaches were used:

- Measuring the dC/dt for mosses in stands of different ages of recovery since fire and fitting a curve of C and time with equation (2). At each identified postburn site, transects were conducted across a variety of soil drainage classes to collect samples for inventories of biomass (trees and understory), accumulating slash, moss, and soil.
- Using <sup>14</sup>C to determine time to construct a curve of cumulative C inventory versus time at a single site (to which equation (2) is fit and I and k determined). In moss layers, we use the bomb- <sup>14</sup>C signal recorded in growing mosses (particularly Sphagnum); in humic and mineral soil layers, we use standard radiocarbon 'age' calculations. This approach assumes that time information, derived from macrofossils picked from the soil or moss sample, is representative of C dynamics for the bulk sample (not particularly true for feather mosses).

## **4. Equipment**

### **4.1 Sensor/Instrument Description**

Shovel, eyes, and sample bags. Lab Equipment - Carlo Erba NA1500 carbon and nitrogen combustion analyzer; vacuum lines for purification of CO<sub>2</sub> from combusted samples and graphite target preparation. Accelerator mass spectrometer (AMS) used for <sup>14</sup>C measurement is described in Southon et al. (1992) and Trumbore (1993).

#### **4.1.1 Collection Environment**

Samples were collected under all environmental conditions.

#### **4.1.2 Source/Platform**

Ground.

#### **4.1.3 Source/Platform Mission Objectives**

None given.

#### **4.1.4 Key Variables**

Soil temperature, sample depth, air temperature, site descriptions,  $\delta^{13}\text{C}$ ,  $\delta^{14}\text{C}$ , CO<sub>2</sub> concentration, pH of the soil, volumetric and gravimetric soil, bulk density, and organic C and N.

#### **4.1.5 Principles of Operation**

None given.

#### **4.1.6 Sensor/Instrument Measurement Geometry**

None given.

#### **4.1.7 Manufacturer of Sensor/Instrument**

None given.

### **4.2 Calibration**

#### **4.2.1 Specifications**

None given.

#### **4.2.1.1 Tolerance**

None given.

#### **4.2.2 Frequency of Calibration**

None given.

#### **4.2.3 Other Calibration Information**

None given.

### **5. Data Acquisition Methods**

Special pits were equipped with thermistors (for monitoring soil temperature), Time Domain Reflectometry (TDR) probes (for monitoring soil water content), and soil gas probes (1/8" stainless steel tubing, perforated at one end and inserted 50 to 100 cm laterally into the soil pit wall, capped with 1/8" swagelock union fittings sealed with a septum). Further details are given in Winston et al. (1997), and in Section 4, below.

Gas samples were obtained using gas-tight syringes, <10 cc for soil CO<sub>2</sub> (made using a LI-COR and the method of Davidson and Trumbore (1995) and CH<sub>4</sub> measurements (made by flame ionization detector gas chromatography). Soil samples are sieved (to <2 mm) to remove rocks and large roots. We have quantified how much of this material was removed, and estimated the amount of C and N contained in the larger fractions. We report bulk density or carbon inventory data of the <2 mm fraction, then add the >2 mm portion back in to determine total bulk density and C inventory. In clay soils, this is a less important correction than in the sandy, gravelly soils (an example of where these data are needed is in the very gravelly soils found at the Northern Study Area (NSA) Young Jack Pine (YJP) site). The samples are then homogenized, split, and in some cases ground to <100 mesh for chemical analyses.

Laboratory measurements are described below:

#### **Bulk density**

Bulk density is measured by determining the oven dry weight of a specific volume of soil. Field sampling utilized a 'box' of known area for collection of organic samples in upper soil horizons (such as mosses and litter layers). The area sampled was generally 12 cm x 12 cm. Samples of generally less than 7 cm depth were taken. Note that the depths are not as well determined as the area, therefore areally expressed data (gC/cm<sup>2</sup>) should be used in these layers with more confidence than the bulk density data.

In deeper soil layers, the bulk density data were measured using several small cores (roughly 3.5 cm diameter by 5 cm in length) that were pushed into the pit wall.

#### **%N, %C and %CaCO<sub>3</sub>**

These measurements were performed with a commercial combustion analyzer (Carlo Erba NA1500). This instrument flash-combusts organic matter, oxides all C to CO<sub>2</sub> and reduces all N to N<sub>2</sub>, then separates these gases chromatographically, and detects them with a thermal conductivity detector. The detector response for C and N is determined by combusting known quantities of C and N-containing pure compounds. Combusting empty capsules determine blanks, due to the presence of small amounts of C in the tin boats used to hold the sample (for C) or to small amounts of residual air (for N<sub>2</sub>). The combustion analyzer will oxidize both organic carbon and inorganic carbonates to CO<sub>2</sub>. The Lake Agassiz clays underlying many of the soils in the NSA contain significant amounts of inorganic CaCO<sub>3</sub>. To determine both CaCO<sub>3</sub> and organic C content, each sample is analyzed twice: once for total carbon and once after it has been acidified to remove calcium carbonate. The %CaCO<sub>3</sub> is

then the Total %C minus the %C due to organics. Uncertainties are still being investigated for this equipment in the Irvine laboratory, but in general %C values are reproducible to +/- 0.05%C (organic) and %N.

#### <sup>14</sup>C

Carbon-14 is measured by accelerator mass spectrometry of graphite targets prepared from CO<sub>2</sub> (see one of several references, including Trumbore, 1995). Samples (of 1-2 mg carbon equivalent) are combusted in vacuum in quartz tubes with cupric oxide wire at 900 °C. The resulting CO<sub>2</sub> is purified cryogenically, then reduced to graphite coating cobalt powder in a sealed Pyrex tube at 500-550 °C with zinc and titanium hydride powder. AMS measurements were made at the Lawrence Livermore National Laboratory Center for Accelerator Mass Spectrometry. One sigma precision is usually +/- 8-10 per mil (0.8-1.0 % Modern), and overall accuracy (based on repeated measurements of substandards prepared in the same way as samples) is 1.0-1.5% of Modern (10-15 per mil). We have noted what was measured for <sup>14</sup>C, as specific fractions of the organic C are measured; these fractions include macrofossils (sphagnum leaves, fine root hairs, deciduous leaves, or charcoal), and chemically treated samples (residue after treatment with 0.5 N HCl).

## 6. Observations

### 6.1 Data Notes

The table below lists soil classification (by order, subgroup, and soil type) of soil pits in this study. This information enables the user to spatially link soils data from this study to the TE-20 Soils Data over the NSA-MSA and Tower Sites in Raster Format and TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format. See TE-20 soils data documentation, TE-20 Soils Report, and Soil Classification Working Group (1998) for detailed description of soil classification.

Soil Pit	Order	Sub-group	Soil Type
-----	-----	-----	-----
Fenc1	ORGANIC	TYF	FCD
Fent1	ORGANIC	TYF	FEN
Fent2	ORGANIC	TYF	FEN
Fent3	ORGANIC	TYF	FEN
FF1	LUVISOLIC	OGL	SWK
FFJ11	LUVISOLIC	OGL	WBW
FFJ12	GLEYSOLIC	OG	MDR <sub>p</sub>
FW10	GLEYSOLIC	OG	MDR <sub>v</sub>
FW9	LUVISOLIC	OGL	SWK
GR1	LUVISOLIC	OGL	WBW
GR2	LUVISOLIC	OGL	SWK
GR3	GLEYSOLIC	OG	MDR <sub>p</sub>
GR4	GLEYSOLIC	OG	MDR
GR5	LUVISOLIC	OGL	WBW
GRC12	LUVISOLIC	OGL	SWK
GRC13	CRYOSOLIC	TFIOC	NIC
GRMJ1 1	CRYOSOLIC	TFIOC	NIC
GRS1	BRUNISOLIC	EDYB	PCP
OBS1	GLEYSOLIC	OLG	LPR <sub>p</sub>
OBSP11	LUVISOLIC	OGL	SWK
OBSP9	CRYOSOLIC	TFIOC	NIC
OBSP9S	CRYOSOLIC	TFIOC	NIC
OJP1	BRUNISOLIC	EDYB	PCPh
OJP2 . BD	BRUNISOLIC	EDYB	PCP

OJPG4	BRUNISOLIC	EDYB	PCP
Palsa5	CRYOSOLIC	MEOC	PAA
SOAB1	LUVISOLIC	OGL	SWK
SOBA1 2	CRYOSOLIC	TFIOC	NIC
SOBA1 3	CRYOSOLIC	TFIOC	NIC
SOBA1 4	CRYOSOLIC	TFIOC	NIC
T3H	CRYOSOLIC	TFIOC	NIC
YJP1	BRUNISOLIC	EDYB	PCP
YJPK1	BRUNISOLIC	EDYB	PCP
YJPK2	BRUNISOLIC	EDYB	PCP

bog  
zoltai

SOILDEV = Soil development (soil classification).

Order	Sub-Group
-----	-----
Brunisolic	
EDYB	Eluviated Dystric Brunisol
GLEDYB	Gleyed Eluviated Dystric Brunisol
EEB	Eluviated Eutric Brunisol
GLEEB	Gleyed Eluviated Eutric Brunisol
Gleysolic	
OHG	Orthic Humic Gleysol
RHG	Rego Humic Gleysol
OG	Orthic Gleysol
FEG	Ferric Gleysol
OLG	Orthic Luvic Gleysol
HULG	Humic Luvic Gleysol
Luvisolic	
OGL	Orthic Gray Luvisol
DGL	Dark Gray Luvisol
GLGL	Gleyed Gray Luvisol
GLDGL	Gleyed Dark Gray Luvisol
Organic	
TYF	Typic Fibrisol
MEF	Mesic Fibrisol
TF	Terric Fibrisol
TMEF	Terric Mesic Fibrisol
HYF	Hydric Fibrisol
TYM	Typic Mesisol
FIM	Fibric Mesisol
TM	Terric Mesisol
TFIM	Terric Fibric Mesisol
THUM	Terric Mesic Humisol
TH	Terric Humisol
TFIH	Terric Fibric Humisol
TMEH	Terric Mesic Humisol

Cryosolic	
OSC	Orthic Static Cryosol
RSC	Regosolic Static Cryosol
OTC	Orthic Turbic Cryosol
RTC	Regosolic Turbic Cryosol
FIOC	Fibric Organic Cryosol
MEOC	Mesic Organic Cryosol
HUOC	Humic Organic Cryosol
TFIOC	Terric Fibric Organic Cryosol
TMEOC	Terric Mesic Organic Cryosol
THUOC	Terric Humic Organic Cryosol

#### VARIANT

Code	Class
c	Cryic
l	Lithic
p	Peaty

SOIL TYPE (See TE-20 Soils Report for descriptions of soil types.)

ATK	- Atik
	BDY - Baldy
BGC	- Bog Collapse
BRN	- Brannigan Creek
	BTT - Button
CLK	- Clarke
	CMK - Cormorant Lake
	FCD - Fen Collapse
FEN	- Fen
GRS	- Grass River
	LPR - La Perouse
LWP	- Low Pine
MDR	- Medard
	NIC - Nichols Lake
PAA	- Palsa
PCB	- Partridge Beak
	PCH - Partridge Head
	PCP - Partridge Crop
PKW	- Pakwa
	PLH - Palsa Hummock
	PLT - Plateau
	PPU - Pipun
	ROK - Roe Lake
SWK	- Sipiwesk
	SYB - Sandy Bog
	TBL - Turnbull
TFN	- Thaw Fen
TYL	- Tyrrell
	WBW - Wabowden
WRL	- Warren Landing
	WTP - Wet Pine
	YGP - Young Pine

## SOIL PHASE

### Code

d	Deep
h	Humus
s	Shallow
v	Very deep
w	Very shallow
x	Complex

Note: The TGB-12 and TE-20 raster data sets cover the same area of the NSA-MSA. Both data sets contain a raster image and an attribute file that describes each soil polygon. The TGB-12 raster data was modified to account for the 1981 burn. In this data set polygons with POLYNUM 238 - 248 are within the burn.

## 6.2 Field Notes

None given.

# 7. Data Description

## 7.1 Spatial Characteristics

### 7.1.1 Spatial Coverage

The coordinate information for the various sampled sites is incomplete in the following lists. Where latitude and longitude coordinates exist, they are expressed in degrees and in reference to the North American Datum of 1983 (NAD83).

#### Sites with Coordinate Information

Site Name/Label	Latitude	Longitude
GR1, Gillam Road	55.9055° N	97.7087° W
GR2, Gillam Road	55.9082° N	97.7003° W
GR3, Gillam Road:	55.906° N	97.7098° W
GR4, Gillam Road:	55.9041° N	97.7063° W
GR5, Gillam Road:	55.9055° N	97.7087° W
Gillam Road Transect	55.9055° N	97.7087° W

(The transect starts 100m SW of so82715C, where GR5 was sampled in detail and continues SW parallel to road with sampling approximately every 100m.)

NSA-FEN:	55.91481° N	98.42072° W
NSA-OBS:	55.88007° N	98.48139° W
OJP1:	55.9287° N	98.6248° W
OJP2:	55.9287° N	98.6248° W
NSA-OJP:	55.92842° N	98.62396° W
YJP1:	55.8952° N	98.28686° W
NSA-YJP:	55.89575° N	98.28706° W
FF1:	55.906° N	98.949° W
SLJ1:	55.0667° N	98.5083° W

Sites with No Coordinate Information Available

Site Name/Label	Location Description
SLJ2	Transect, approximately 500 m NNW of SLJ1
SLJ3	Transect, approximately 500 m NNW of SLJ2
SLJ4	Transect, approximately 500 m NNW of SLJ3
SLJ5	Transect, approximately 500 m NNW of SLJ4
SLJ6	Transect, approximately 500 m NNW of SLJ5
SLJ7	Transect, approximately 500 m NNW of SLJ6
SLJ8	Transect, approximately 500 m NNW of SLJ7
FFJ11	Footprint River, Footprint fire 1989 burn site, west side of Footprint River Bridge.
FFJ12	Footprint River, Footprint River, 1989 burn, west side of Footprint River bridge, poorly drained site.
SOBA0	Soab River 1956 burn, Site 0 on the transect; on the ridge of the SOAB 1956 burn.
SOBA1	Soab River, 1956 burn, South of Thompson on Hwy 391/6 just north of the Soab River on the west side of road.
SOBA2	Soab River, 1956 burn, 500m North of SOBA1
SOBA3	Soab River, 1956 burn, 500m North of SOBA2
SOBA4	Soab River, 1956 burn, 500m North of SOBA3
SOBA5	Soab River, 1956 burn, 500m North of SOBA4
SOBA6	Soab River, 1956 burn, 500m North of SOBA5
SOBA7	Soab River, 1956 burn, 500m North of SOBA6
SOBA8	Soab River, 1956 burn, 500m North of SOBA7
SOBA9	Soab River, 1956 burn, 500m North of SOBA8
SOBA10	Soab River, 1956 burn, 500m North of SOBA9
SOBA11	Soab River, 1956 burn, 500m North of SOBA10
SOBA12	Soab River, 1956 burn, South of Thompson just north of the Soab River.
SOBA13	Soab River, 1956 burn, South of Thompson just north of the Soab River on Hwy 391.
SOBA14	Soab River, 1956 burn, South of Thompson just north of the Soab River on Hwy 391.
SOBH1	Soab River
T3H	No location information is available.
FFJ1	Footprint fire 1989 burn site, far into Footprint burn, approximately 1Km north of FF1.
FFJ2	near the Footprint River along the FFJ transect between FFJ1 and 3.
YJPK1	Young Jack Pine, 1964 burn, Veldhuis Map name: Partridge soil; code pcp
YJPK2	Young Jack Pine, 1964 burn, Veldhuis Map name: Partridge soil; code pcp
BOG	No location information available.
OBS11	Old Black Spruce, Veldhuis Mapped name: Sipewisk.
OBSF3	Old Black Spruce, End of TGB spur, 2.5 m east of small corral.
OBSF4	Old Black Spruce, NW corner of boardwalk-TGB spur, 3m N and 3m W of intersection of spur and boardwalk.
OBSP9	Old Black Spruce, Veldhuis mapped name: Nicohols Lake (NIC)

OBS1	Old Black Spruce, Site is very wet, seasonally if not perennially somewhat frozen. Bear east on catwalk, south on first spur, east about 5m
OBS2	near Old Black Spruce
FW10	Gillam Road: 1992 burn, near 89/90 km marker on Gillam Road
GRS1	Gillam Road: 1994 burn.
GRC12	Gillam Road: unburned control for 1992 burn, near 89/90 km marker on Gillam Road, North side of road, across from 1992 burn.
GRC13	Gillam Road: unburned control for 1992 burn, near 89/90 km marker on Gillam Road, North side of road, across from 1992 burn.
GRJ11	Gillam Road: Cabin site, 1964 burn.
Gillam Road:	Near 89/90 marker on Gillam Road.
FW3	Gillam Road: Near 89/90 marker on Gillam Road.
FW9	Gillam Road: 1992 burn, near 89/90 km marker on Gillam Road

### 7.1.2 Spatial Coverage Map

Not available.

### 7.1.3 Spatial Resolution

None given.

### 7.1.4 Projection

Not applicable.

### 7.1.5 Grid Description

Not applicable.

## 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage

Soil carbon measurements were made from August 1993 to July 1996.

### 7.2.2 Temporal Coverage Map

Not applicable.

### 7.2.3 Temporal Resolution

The temporal resolution of the measurements was variable.

## 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name
SITE_NAME
SUB_SITE
DATE_OBS
SOIL_DEPTH
SOIL_TEMP
AIR_TEMP_1M

SNOW\_DEPTH  
 BASAL\_DEPTH  
 SITE\_COMMENTS  
 COVER\_TYPE  
 DEL\_13C  
 DEL\_14C  
 DEL\_14C\_DEPTH  
 CO2\_CONC  
 FLAG  
 SOIL\_PH  
 FLD\_VOL\_SOIL\_MOISTURE  
 FLD\_GRAV\_SOIL\_MOISTURE  
 AIR\_DRY\_GRAV\_SOIL\_MOISTURE  
 OVEN\_DRY\_VOL\_SOIL\_MOISTURE  
 OVEN\_DRY\_GRAV\_SOIL\_MOISTURE  
 TOT\_BULK\_DENSITY  
 BULK\_DENSITY\_<2MM  
 ROCK\_>2MM  
 ROOT\_>2MM  
 INORG\_C\_CONTENT  
 ORG\_C\_CONTENT  
 TOT\_C\_CONTENT  
 TOT\_N\_CONTENT  
 C\_N\_RATIO  
 SAMPLING\_MEDIA  
 CRTFCN\_CODE  
 REVISION\_DATE

### 7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
SOIL_DEPTH	The depth below the soil surface at which the measurement was taken.
SOIL_TEMP	The temperature of the soil at the given depth/location.
AIR_TEMP_1M	The temperature of the air at 1 meter above ground level.
SNOW_DEPTH	The depth of snow on the ground.

BASAL_DEPTH	Bottom depth of horizon/sample. Defined the top of the soil (0mm depth) as the top of the living moss layer. The top of each sample is the bottom depth of the sample above it.
SITE_COMMENTS	Descriptive information to clarify or enhance the site information.
COVER_TYPE	The dominant species, vegetation or type of land cover that exists at the location.
DEL_13C	The del 13C is a relative difference between the sample and the PeeDee Belemnite standard, relative to the PeeDee Belemnite standard.
DEL_14C	The del 14C is a relative difference between the sample and the 95% oxalic acid 1 standard, relative to the 95% oxalic acid 1 standard.
DEL_14C_DEPTH	The depth at which the DEL 14C measurements were taken.
CO2_CONC	CO2 concentration.
FLAG	1 means CO2 concentrations are from the amount of CO2 in the 500cc can-- 2 means 13C value given was assumed in correction of the 14C data and 0 means no comments.
SOIL_PH	The pH of the soil sample.
FLD_VOL_SOIL_MOISTURE	Grams of H2O in the field sample per cubic millimeter of volume in the soil horizon.
FLD_GRAV_SOIL_MOISTURE	Grams of water in the field sample per gram oven-dry total soil.
AIR_DRY_GRAV_SOIL_MOISTURE	Grams of water in an air-dried sample per gram of oven-dried soil whose particle size was less than 2mm. Calculation is used to express chemical data on an oven-dry basis.
OVEN_DRY_VOL_SOIL_MOISTURE	Volumetric moisture of oven dried samples.
OVEN_DRY_GRAV_SOIL_MOISTURE	Gravimetric moisture of oven dried samples.
TOT_BULK_DENSITY	The bulk density of all sizes of material, including rocks and coarse roots.
BULK_DENSITY_<2MM	The bulk density of material less than 2mm in size, excluding all rocks and roots that were caught in a 2mm sieve.
ROCK_>2MM	Percent by weight of the rock material greater than 2mm in size (i.e., did not pass through a 2mm sieve) calculated as (grams rock > 2mm)/(total grams of sample).
ROOT_>2MM	Percent by weight of the root material greater than 2mm in size (i.e., did not pass through a 2mm sieve) calculated as (grams root > 2mm)/(total grams of sample).
INORG_C_CONTENT	Percentage of inorganic carbon contained in an oven-dried soil sample whose particles are less than 2mm in size (i.e., passed through a 2mm sieve) calculated as (grams inorganic carbon)/(total grams oven-dried sample).
ORG_C_CONTENT	Percentage of organic carbon contained in an oven-dried soil sample whose particles are less than 2mm in size (i.e., passed through a 2mm sieve) calculated as (grams organic

TOT_C_CONTENT	carbon)/(total grams oven-dried sample). Combustion analysis results, expressed as 100 * (grams C divided by grams air-dry soil) (this includes both organic and inorganic carbon). This analysis is presented on basis of <2mm air-dry soil because lab results can easily be checked but may be calculated as % of oven-dry soil using (%C air-dry basis) * (g oven-dry split)/(g air-dry basis).
TOT_N_CONTENT	Combustion analysis results, expressed as 100*[g N]/[g air dry soil]. Presented on basis of <2mm oven-dry soil.
C_N_RATIO	Contains the ratio of grams of Carbon divided by grams of nitrogen in the soil sample, not expressed as atom ratio.
SAMPLING_MEDIA	What 14C was measured in (e.g. moss, bulk organics).
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

### 7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
SOIL_DEPTH	[millimeters]
SOIL_TEMP	[degrees Celsius]
AIR_TEMP_1M	[degrees Celsius]
SNOW_DEPTH	[millimeters]
BASAL_DEPTH	[millimeters]
SITE_COMMENTS	[none]
COVER_TYPE	[none]
DEL_13C	[per mil]
DEL_14C	[per mil]
DEL_14C_DEPTH	[millimeters]
CO2_CONC	[parts per million]
FLAG	[unitless]
SOIL_PH	[pH]
FLD_VOL_SOIL_MOISTURE	[grams H2O][millimeter <sup>-3</sup> soil]
FLD_GRAV_SOIL_MOISTURE	[grams H2O][gram <sup>-1</sup> dry soil]
AIR_DRY_GRAV_SOIL_MOISTURE	[grams H2O][gram <sup>-1</sup> soil]
OVEN_DRY_VOL_SOIL_MOISTURE	[centimeters <sup>3</sup> H2O][centimeter <sup>-3</sup> soil]
OVEN_DRY_GRAV_SOIL_MOISTURE	[grams H2O][gram <sup>-1</sup> soil]
TOT_BULK_DENSITY	[grams][millimeter <sup>-3</sup> ]
BULK_DENSITY_<2MM	[grams][millimeter <sup>-3</sup> ]
ROCK_>2MM	[percent of total]
ROOT_>2MM	[percent of total]

INORG_C_CONTENT	[percent]
ORG_C_CONTENT	[percent]
TOT_C_CONTENT	[percent of dry soil]
TOT_N_CONTENT	[percent of dry soil]
C_N_RATIO	[grams C][gram <sup>-1</sup> N]
SAMPLING_MEDIA	[none]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

### 7.3.4 Data Source

The source of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	Not applicable
SUB_SITE	Not applicable
DATE_OBS	Investigator
SOIL_DEPTH	investigator
SOIL_TEMP	thermistor
AIR_TEMP_1M	thermometer
SNOW_DEPTH	Investigator
BASAL_DEPTH	Investigator
SITE_COMMENTS	Investigator
COVER_TYPE	Investigator
DEL_13C	Mass spectrometry
DEL_14C	Accelerator mass spectrometry
DEL_14C_DEPTH	Investigator
CO2_CONC	Carlo Erba NA1500
FLAG	Investigator
SOIL_PH	Investigato
FLD_VOL_SOIL_MOISTURE	TDR
FLD_GRAV_SOIL_MOISTURE	Investigator
AIR_DRY_GRAV_SOIL_MOISTURE	Investigator
OVEN_DRY_VOL_SOIL_MOISTURE	TDR
OVEN_DRY_GRAV_SOIL_MOISTURE	Investigator
TOT_BULK_DENSITY	Calculated from BULK_DENSITY_<2MM and BULK_DENSITY_>2MM
BULK_DENSITY_<2MM	Scale
ROCK_>2MM	Investigator
ROOT_>2MM	Investigator
INORG_C_CONTENT	Carlo Erba NA1500
ORG_C_CONTENT	Carlo Erba NA1500
TOT_C_CONTENT	Carlo Erba NA1500
TOT_N_CONTENT	Carlo Erba NA1500
C_N_RATIO	Carlo Erba NA1500
SAMPLING_MEDIA	Investigator
CRTFCN_CODE	Not applicable
REVISION_DATE	Not applicable

### 7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllected
SITE_NAME	NSA-999-999GR	REG-999-SOBH1	None	None	None	None
SUB_SITE	TGB03-FLXCB	TGB12-STM01	None	None	None	None
DATE_OBS	01-AUG-93	21-JUL-96	None	None	None	None
SOIL_DEPTH	0	920	None	None	None	Blank
SOIL_TEMP	-9.6	1.12	None	None	None	Blank
AIR_TEMP_1M	-15.5	-1.3	None	None	None	Blank
SNOW_DEPTH	140	200	None	None	None	Blank
BASAL_DEPTH	0	4640	-999	None	None	Blank
SITE_COMMENTS	N/A	N/A	None	None	None	Blank
COVER_TYPE	N/A	N/A	None	None	None	Blank
DEL_13C	-24.2	-17.28	None	None	None	Blank
DEL_14C	-599.09	675.2	-999	None	None	Blank
DEL_14C_DEPTH	15	3485	-999	None	None	Blank
CO2_CONC	350	11980	-999	None	None	Blank
FLAG	0	2	None	None	None	Blank
SOIL_PH	3.8	8	-999	None	None	Blank
FLD_VOL_SOIL_ MOISTURE	.000222	229.5	-999	None	None	Blank
FLD_GRAV_SOIL_ MOISTURE	-17.87	960	-999	None	None	Blank
AIR_DRY_GRAV_SOIL_ MOISTURE	0	55.86	-999	None	None	Blank
OVEN_DRY_VOL_SOIL_ MOISTURE	3.51	72.26	-999	None	None	Blank
OVEN_DRY_GRAV_SOIL_ MOISTURE	25.98	5802.8	-999	None	None	Blank
TOT_BULK_DENSITY	.000004	2.102	-999	-888	None	Blank
BULK_DENSITY_<2MM	.004	2.713	-999	None	None	Blank
ROCK_>2MM	0	51.5	-999	None	None	Blank
ROOT_>2MM	0	33.649	-999	None	None	Blank
INORG_C_CONTENT	0	5.308	-999	None	-777	Blank
ORG_C_CONTENT	.007	56.16	-999	None	None	Blank
TOT_C_CONTENT	.548	52.25	-999	-888	None	Blank
TOT_N_CONTENT	.003	29.227	-999	-888	None	Blank
C_N_RATIO	.06	448.08	-999	-888	None	Blank
SAMPLING_MEDIA	N/A	N/A	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	26-MAY-95	07-AUG-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.

Maximum Data Value -- The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be

```

unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
instruments detection limits. This is used to
indicate that an attempt was made to determine the
parameter value, but the analysis personnel determined
that the parameter value was below the detection
limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
determine the parameter value. This usually
indicates that BORIS combined several similar but
not identical data sets into the same data base table
but this particular science team did not
measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.

```

The following are wrapped versions of data record from a sample data file on the CD-ROM.

## 8. Data Organization

### 8.1 Data Granularity

All of the TGB-12 NSA soil carbon data are contained in one data set.

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

## **9. Data Manipulations**

### **9.1 Formulae**

#### **9.1.1 Derivation Techniques and Algorithms**

None.

### **9.2 Data Processing Sequence**

#### **9.2.1 Processing Steps**

None given.

#### **9.2.2 Processing Changes**

None given.

### **9.3 Calculations**

#### **9.3.1 Special Corrections/Adjustments**

None given.

#### **9.3.2 Calculated Variables**

None given.

### **9.4 Graphs and Plots**

None given.

## **10. Errors**

### **10.1 Sources of Error**

None given.

### **10.2 Quality Assessment**

#### **10.2.1 Data Validation by Source**

None given.

#### **10.2.2 Confidence Level/Accuracy Judgment**

None given.

#### **10.2.3 Measurement Error for Parameters**

None given.

#### **10.2.4 Additional Quality Assessments**

None given.

#### **10.2.5 Data Verification by Data Center**

The data were examined for general consistency and clarity.

## **11. Notes**

### **11.1 Limitations of the Data**

None given.

### **11.2 Known Problems with the Data**

None given.

### **11.3 Usage Guidance**

None given.

### **11.4 Other Relevant Information**

None given.

## **12. Application of the Data Set**

These data can be used to spatially extrapolate the storage of carbon in boreal soils. In addition, the data should prove useful to modelers who are looking at changing soil carbon amounts.

## **13. Future Modifications and Plans**

None given.

## **14. Software**

### **14.1 Software Description**

None given.

### **14.2 Software Access**

None given.

## **15. Data Access**

The TGB-12 soil carbon data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

### **15.1 Contact Information**

For BOREAS data and documentation please contact:

ORNL DAAC User Services  
Oak Ridge National Laboratory  
P.O. Box 2008 MS-6407  
Oak Ridge, TN 37831-6407  
Phone: (423) 241-3952  
Fax: (423) 574-4665  
E-mail: [ornldaac@ornl.gov](mailto:ornldaac@ornl.gov) or [ornl@eos.nasa.gov](mailto:ornl@eos.nasa.gov)

## **15.2 Data Center Identification**

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics  
<http://www-eosdis.ornl.gov/>.

## **15.3 Procedures for Obtaining Data**

Users may obtain data directly through the ORNL DAAC online search and order system [<http://www-eosdis.ornl.gov/>] and the anonymous FTP site [<ftp://www-eosdis.ornl.gov/data/>] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

## **15.4 Data Center Status/Plans**

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

# **16. Output Products and Availability**

## **16.1 Tape Products**

None.

## **16.2 Film Products**

None.

## **16.3 Other Products**

These data are available on the BOREAS CD-ROM series.

# **17. References**

## **17.1 Platform/Sensor/Instrument/Data Processing Documentation**

None.

## **17.2 Journal Articles and Study Reports**

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### **17.3 Archive/DBMS Usage Documentation**

None.

## **18. Glossary of Terms**

None given.

## **19. List of Acronyms**

AMS	- Accelerator Mass Spectrometer
ASCII	- American Standard Code for Information Interchange
BOREAS	- BOReal Ecosystem-Atmosphere Study
BORIS	- BOREAS Information System
CD-ROM	- Compact Disk-Read-Only Memory
DAAC	- Distributed Active Archive Center
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
GIS	- Geographic Information System
GSFC	- Goddard Space Flight Center
HTML	- Hyper-Text Markup Language
MSA	- Modeling Sub-Area
NAD83	- North American Datum of 1983
NASA	- National Aeronautics and Space Administration
NSA	- Northern Study Area
OA	- Old Aspen
OBS	- Old Black Spruce
OJP	- Old Jack Pine
ORNL	- Oak Ridge National Laboratory
PANP	- Prince Albert National Park
SOM	- Soil Organic Matter
SSA	- Southern Study Area
TDR	- Time Domain Reflectometry
TE	- Terrestrial Ecology
TGB	- Trace Gas Biogeochemistry
URL	- Uniform Resource Locator
USGS	- United States Geological Survey
YJP	- Young Jack Pine

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When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

The TGB-12 team published the data in two USGS open file reports (O'Neill et al., 1995a, 1995b). Please reference the reports or contact Susan Trumbore.

If using data from the BOREAS CD-ROM series, also reference the data as:

Trumbore, S., J. Harden, and E. Sundquist, "Input, Accumulation and Turnover of Carbon in Boreal Forest Soils." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

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Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

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